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Effects of Sprinkler Irrigation With Municipal Sewage Wastewater

And Cutting Management on Nutritive Value, Growth, and Disease Severity of Reed Canarygrass

ABSTRACT

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Reed canarygrass (*Phalaris arundinacea* L.) is well suited for renovating sewage effluents applied as sprinkler irrigation on cropland. This publication describes the effects of irrigation, cutting management, season, and year on the quality, growth, and disease severity of reed canarygrass. A group of 12 genotypes in nonirrigated and irrigated plots under 2- and 3-cut management was assayed for in vitro digestible dry matter (IVDDM) and crude protein (CP) after spring and fall harvests in 1975, 1977, and 1978. The severity of tawny blotch disease caused by *Stagonospora foliicola* (Bres.) Bubak was rated in summer and fall. A group of 13 additional genotypes was assayed for all traits in 1977 and 1978.

Irrigation vs. no irrigation had little effect on IVDDM or plant height, but irrigated plants were slightly lower in CP than nonirrigated plants in fall harvests. Tawny blotch was more severe in irrigated than in nonirrigated plots because of the longer periods of leaf wetness and more moist environment in the plant canopy. Severe leaf disease may also reduce forage quality. The overall results indicated that susceptibility to tawny blotch was not closely linked with the other traits. Two-cut management vs. conventional 3-cut had deleterious effects on all traits in the fall harvests, that is, reduced IVDDM, CP, and plant growth, and increased severity of tawny blotch disease. The prolonged growth under the 2-cut system would seriously reduce the feeding quality of the forage.

KEYWORDS: *Phalaris arundinacea* L., forage crop, forage quality, forage digestibility, disease severity, *Stagonospora foliicola* (Bres.) Bubak

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EFFECTS OF SPRINKLER IRRIGATION WITH MUNICIPAL SEWAGE WASTEWATER AND CUTTING MANAGEMENT ON NUTRITIVE VALUE, GROWTH, AND DISEASE SEVERITY OF REED CANARYGRASS[1]

By K.E. Zeiders and R.T. Sherwood[2]

Reed canarygrass (*Phalaris arundinacea* L.) is perhaps the best forage grass for utilizing the nutrients in municipal and industrial waste effluents applied as irrigation on land areas (Sopper and Kardos 1972, Marten et al. 1979). The hay is an acceptable feed for beef cattle (National Academy of Sciences 1976).

In a study of 12 reed canarygrass clones at State College, PA, the tawny blotch disease incited by *Stagonospora foliicola* (Bres.) Bubak was much more severe on irrigated than nonirrigated plants (Zeiders and Sherwood 1977a). Clones varied widely in resistance, and there were significant cutting management by harvest interactions. Disease severity was reduced by using a 3-cut-per-year management system rather than a 2-cut system. These results with tawny blotch suggested a need to examine the effects of irrigation and cutting management practices on forage quality. This publication describes the effects of irrigation, cutting management, season, and year on in vitro digestible dry matter (IVDDM), crude protein (CP), plant height, and tawny blotch in two groups of reed canarygrass genotypes. The stability of individual reed canarygrass genotypes for these traits in relation to environmental variables has been reported elsewhere (Zeiders and Sherwood 1985).

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MATERIALS AND METHODS

Field Plantings

A replicated spaced planting of 12 reed canarygrass genotypes was established on May 1-2, 1974. An adjacent planting of 13 additional genotypes was established on May 11, 1976. Previous studies showed that these 25 clones varied widely in palatability and indole alkaloid content (Kendall and Sherwood 1975, Marten et al. 1973), reaction to the frit fly (*Oscinella frit* L.) (Byers and Sherwood 1979), and resistance to several leaf spot diseases (Zeiders 1975, 1976, 1979; Zeiders and Sherwood 1977a, 1977b; Sherwood et al. 1978).

The research area was a 9.2 by 200-m strip within a 6.5-ha field of silage maize (*Zea mays* L.) that was part of The Pennsylvania State University Wastewater Renovation and Conservation Project located 3 km north of State College. The soil was a Hagerstown silt loam, a member of the fine, mixed mesic family of Typic Hapludalfs. The design was a split plot experiment within each of two irrigation treatments (irrigated and nonirrigated). There were four replicated irrigated blocks and four replicated nonirrigated blocks. There were two main plots within each replicate block, and cutting management treatments were assigned at random to the main plots. Ramets of the 12 clones (subplots) were planted randomly in 3 rows of 4 plants on 96-cm centers within each main plot. The 13 clones were planted adjacent to the 12 clones. In the analysis of variance, irrigation treatments were treated as locations as in the example in Federer (1955, table 10.16). Plants spread laterally to within about 30 cm of each other, but the area between rows was cultivated frequently to control weeds.

Management Treatments

Four irrigation/cutting management treatments were imposed each year: (1) nonirrigated, two cuts; (2) nonirrigated, three cuts; (3) irrigated, two cuts; and (4) irrigated, three cuts. Irrigated plots were sprayed with municipal sewage effluent from revolving overhead sprinklers once or twice a week from late May through early September each year. Nonirrigated plots received only rainfall which, during the periods of irrigation, was 34.6, 36.1, 47.2, 31.1, and 22.3 cm in 1974, 1975, 1976, 1977, and 1978, respectively. In 1974, 12-clone plots were fertilized before planting with nitrogen (N), phosphorus (P), and potassium (K) at 118 kg/ha, respectively. The amounts of plant nutrients applied to irrigated and nonirrigated plots from 1975 through 1978, and times of application, are given in table 1. In 1976, the 13 clones were topdressed with N, P, and K as shown in table 1 to aid in establishment. Pulverized limestone ($CaCO_3$) and magnesium (ag grade Magox) were applied only to the nonirrigated blocks in spring 1977 at 5600 and 145 kg/ha, respectively, as recommended by soil

tests. In spring 1978, the irrigated blocks were topdressed with lime at 2240 kg/ha according to soil test. It was not possible to apply equivalent amounts of nutrient elements to nonirrigated and irrigated blocks, because the amounts of nutrients in the effluent varied each year and were not calculated until irrigation was completed. Therefore, we relied on soil tests as a guide for application of fertilizers to nonirrigated blocks.

The spring harvests for the 2-cut and 3-cut plots were made on June 4, 1975, June 8, 1977, and June 6, 1978. The fall harvests were made on October 1-3, 1975, October 6, 1977, and October 3, 1978. Summer (second) harvests of the 3-cut plots were made on July 31, 1975, August 5, 1977, and August 3, 1978. Plants were not clipped the year of establishment. Individual plants were hand clipped to 8-cm stubble height. The forage was dried in cloth bags with forced air at 61°C and ground in a Wiley[3] mill with 1 mm openings in the screen.

Evaluation Procedures

No analysis of harvested forage was made in 1976, because leaves were damaged in the spring by herbicide drifting from a nearby experiment. IVDDM and CP were measured for the spring and fall harvests for 12 clones in 1975, and for all clones in 1977 and 1978. Samples were analyzed for IVDDM using the Tilley and Terry (1963) technique as modified by Barnes et al. (1971). Ground samples of 0.25 g were weighed to the fourth decimal. Crude protein was determined by the Kjeldahl method using a 1.0-g sample weighed to the fourth decimal. CP and IVDDM were not measured at the summer harvest because sampling of the limited material of the 2-cut spaced plants at that time would have set back development of the plants.

Tawny blotch developed naturally and was the most prevalent disease. Severity was rated on a scale of 1 = no disease to 9 = very severe disease just before summer and fall harvests. Disease was not rated at spring harvests because of insufficient disease development. Plant height was

[3]Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

measured before each harvest. In the analyses, the fall height for the 3-cut treatments is the sum of the heights of the second (summer) and third (fall) cuttings, to provide a closer comparison with the total growth of the 2-cut treatments.

Statistical Analyses

The data were analyzed by four-way and five-way analyses of variance. The 12- and 13-clone data were analyzed separately. Values analyzed and reported were the means of the 12 or 13 clones.

RESULTS AND DISCUSSION

IVDDM

Irrigation

In spring harvests, nonirrigated plants of the 12-clone group had higher IVDDM than irrigated plants in 1975 (table 2). However, this result was reversed for the 12-clone group in 1978, and the 13-clone group in 1977, resulting in a significant year by irrigation interaction (data for interactions not given). In fall harvests, there were no significant differences between irrigated and nonirrigated plants except for the 12-clone group in 1978 (table 3). Overall, IVDDM was not strongly influenced by application of effluent.

Cutting Management

In spring harvests, 3-cut plants had higher IVDDM than 2-cut plants in 1977 and 1978 for 12 clones, and in 1978 for 13 clones (table 2). Because 2- and 3-cut plants had equal time for growth in the spring, one might expect them to have equivalent IVDDM. Although the actual differences were not large, the significantly lower IVDDM values for 2-cut plots suggested a residual effect from the previous year's management on spring growth. The year by cutting management interaction was significant, but the irrigation by cutting management was not.

In fall harvests, the IVDDM content of the 2-cut material was substantially lower than that of 3-cut plants--often as much as 8 to 15 percent lower. The severe reduction in IVDDM and CP due to prolonged growth under the 2-cut system would seriously reduce the feeding quality of the forage.

Harvest

In 1975, fall-harvested forage always had significantly higher IVDDM than that from the spring harvest (table 2). In 1977 and 1978, however, forage harvested in the spring had higher IVDDM than in the fall, indicating the importance of weather upon nutrient composition of the plants. In both clone groups, the differences in IVDDM percentage between spring and fall harvests were significant each year.

Year

The effect of year on IVDDM in spring was more pronounced than the effect of irrigation or cutting management (table 2). The year effect was less pronounced in the fall, although the 12 clones showed significantly higher IVDDM in fall 1975 than in 1977 or 1978. The differences in IVDDM content among years were significant for spring and fall harvests with one exception.

In summary, the factors showing the greatest effect on IVDDM were cutting management and year. Time of harvest had a lesser effect, and irrigation the least effect.

Crude Protein

Irrigation

In spring 1975, nonirrigated plants had higher CP than irrigated plants; however, in 1977 and 1978, the irrigated plants had higher CP in the spring (table 2), resulting in a significant year by irrigation interaction.

In fall 1977 and 1978, irrigated plants had lower CP than nonirrigated plants. This was opposite to the trend in spring and accounted for a significant harvest by irrigation effect each year. Trends for CP in spring were similar to the IVDDM trends. Irrigation affected CP to a greater extent than it affected IVDDM in both spring and fall. This result differs somewhat with results reported by Marten et al. (1980). In 3 years of their 4-year study, the mean CP percentage of reed canarygrass in irrigated plots was higher than in control plots. However, their data were presented as yearly averages and effects of season were not reported.

Cutting Management

Unlike the effect on IVDDM, cutting management did not influence CP in spring (table 2). In fall, CP content of 3-cut material always markedly exceeded that of 2-cut material, undoubtedly because 2-cut plants included a higher proportion of diseased and senescent leaves. In fall, clonal means for CP in 2-cut irrigated plants were 13.3 to 18.6 percent, while those of 3-cut irrigated plants were 14.3 to 25.1 percent. Even under the most adverse conditions, CP levels of reed canarygrass were above minimum requirements for beef cattle (National Academy of Sciences, 1976). Asay et al. (1968) earlier reported a similar decline in CP with extension of the growth period before cutting.

Harvest

In 3-cut plants, CP was appreciably higher in the fall harvest than in the spring (table 2). Even in the 2-cut plants, fall CP was equal to or higher than spring CP. These results differ with those of Bole and Bell (1978) who reported that irrigated reed canarygrass had higher CP in a late June harvest than in late August. They applied N only in spring before irrigation, and it was apparently exhausted in the first growth period. In contrast, we applied N to irrigated and nonirrigated plots in both June and August 1977 and 1978. Differences in CP content between spring and fall harvests were significant each year for both clone groups.

Year

Crude protein content was appreciably higher in 1977 than in 1978 in both spring and fall harvests (table 2). This may be due in part to the larger amounts of N applied in the effluent in 1977 than in 1978 and the reduced amount of annual rainfall for 1978 (22.3 cm). Differences in CP content among years were significant for spring and fall harvests for both clone groups.

Plant Height

We did not record dry matter yields because clones differed in the amount of lateral spread, and yield of the spaced plants could not be determined on a hectare basis. Instead, we measured tiller height as an indication of the influence of environment and management on plant growth.

Irrigation

In spring 1977, irrigated plants in the 12-clone group were taller than nonirrigated plants, but in 1978 nonirrigated plants were taller (table 2). The year by irrigation interaction was significant.

There were no significant effects of irrigation on plant height at fall harvests. Reed canarygrass is reported to grow under a relatively wide range of soil moisture conditions (Decker et al. 1967). Apparently the rainfall of 1977 and 1978 provided sufficient moisture for growth, and the addition of about 60 to 80 cm of effluent did not enhance or retard growth. The effects of factors such as fertilizer application, leaching, and soil compaction could not be determined in this experiment.

Cutting Management

In spring 1978, 2-cut plants were taller than 3-cut plants, even though the growth period was the same for both treatments. This finding indicated a possible residual effect of the previous years' management on spring growth. Horst and Nelson (1979) reported that fall growth of tall fescue plants (*Festuca arundinacea* Schreb.) that had been water-stressed during summer was greater than plants that were irrigated and that compensatory growth following drought stress was still evident the following spring as indicated by greater forage yield.

In fall harvests, the combined height for 3-cut plants always exceeded that of 2-cut plants (table 2). This result indicated that 2-cut management not only lowered quality (IVDDM and CP) but also growth. These effects may be due in part to the greater buildup of leaf diseases in the 2-cut plots (Zeiders and Sherwood 1977a).

Harvest and Year

Fall height of 3-cut plants was always greater than spring height (table 2), and spring height of 2-cut plants usually exceeded the fall height. Plant height was greater in 1978 than 1977 for both clone groups in both spring and fall. Differences in plant height between spring and fall harvests and among years were significant each year, except for the year effect in 1978.

Tawny Blotch

Tawny blotch was more severe in irrigated than nonirrigated plots in the summers of 1975 and 1977 and the fall of 1975 (table 2). The disease was about equally severe on irrigated and nonirrigated plants in fall 1977 and 1978, and was generally more severe on nonirrigated plants in 1977 and 1978 than in 1975. Tawny blotch developed to a greater extent on plants that were uncut between spring and fall (2-cut plants) than on the plants cut 3 times yearly. These differences in disease severity at fall harvests were significant every year for both clone groups. Correlation analysis indicated that tawny blotch was not associated with plant height and usually not with CP. There was a significant negative correlation between tawny blotch and IVDDM for nonirrigated plants in fall 1977, suggesting a possible adverse effect of severe infection on IVDDM. The overall results indicated that susceptibility to tawny blotch was not closely linked with the other traits.

Tawny blotch is favored by prolonged wet periods (Zeiders 1975). The results of this study suggest that (1) more inoculum of *S. foliicola* was present in the field in 1977 and 1978 than when the plots were first established, and (2) there was sufficient moisture and high relative humidity in 1977 and 1978 to promote good disease development even in the absence of supplemental irrigation.

CONCLUSIONS

Our data show that in two groups of reed canarygrass genotypes, 2-cut management vs. conventional 3-cut had deleterious effects on all traits evaluated, that is, reduced IVDDM, CP, and plant growth, and increased severity of tawny blotch disease in fall-harvested material. The prolonged growth under the 2-cut system would seriously reduce the feeding quality of the forage. Irrigation vs. no irrigation had little effect on IVDDM or plant height, but irrigated plants were slightly lower in CP than nonirrigated plants in fall harvests. Tawny blotch and possibly other fungal diseases can be expected to be more severe in irrigated than in nonirrigated plots because of the longer periods of leaf wetness and more moist environment in the plant canopy. Severe leaf disease may reduce forage quality. The overall results indicated that susceptibility to tawny blotch was not closely linked with the other traits.

Table 1. Applications of plant nutrients to nonirrigated and irrigated reed canarygrass plots during four years

Year	Clone group	Irrigation treatment	Nutrients applied in fertilizer[1/]			Effluent applied	Nutrients applied in effluent			Total		
			N	P	K		N	P	K	N	P	K
			----- kg/ha-----			-- cm --	----- kg/ha -----			--- kg/ha ---		
1975	12 clones	Nonirrigated	112	67	134	0	0	0	0	112	67	134
		Irrigated	0	0	0	65	205	66	77	205	66	77
1976	12 clones	Nonirrigated	112	195	372	0	0	0	0	112	195	372
		Irrigated	0	0	0	71	77	26	68	77	26	68
	13 clones	Nonirrigated	56	67	134	0	0	0	0	56	67	134
		Irrigated	140	34	67	71	77	26	68	217	60	135
1977	25 clones	Nonirrigated	82	0	0	0	0	0	0	82	0	0
		Irrigated	74	0	0	81	236	33	69	310	33	69
1978	25 clones	Nonirrigated	112	0	202	0	0	0	0	112	0	202
		Irrigated	0	45	180	60	55	10	31	55	55	211
Yearly average[2/]		Nonirrigated	104	65	177	0	0	0	0	104	65	177
		Irrigated	18	11	45	69	143	34	61	161	45	106

[1/] N supplied as urea, P as superphosphate, and K as KCl. Application dates. Nonirrigated blocks: 1975--N, May 7 and June 10; P and K, May 7. 1976--N (12 clones), April 16 and June 10; N (13 clones), June 11; P and K (12 clones), April 16; P and K (13 clones), June 11. 1977--N, June 10 and August 5. 1978--N, June 13 and August 4; K, April 26. Irrigated blocks: 1976 (13 clones only)--N, June 11 and August 11; P and K, June 11. 1977--N, June 10 and August 5. 1978--N, June 13 and August 4; P and K, April 26.

[2/] Does not include nutrients applied to 13 clones in 1976, the establishment year.

Table 2. Mean values[1/] for in vitro digestible dry matter (IVDDM), crude protein (CP), plant height, and tawny blotch reaction for 2 groups of reed canarygrass clones in response to irrigation with municipal sewage wastewater and cutting treatments within 2 harvests and 3 years [2/]

Irrigation/cutting management treatment	Spring harvest							Fall harvest						
	12 clones				13 clones			12 clones				13 clones		
	1975	1977	1978	Avg.	1977	1978	Avg.	1975	1977	1978	Avg.	1977	1978	Avg.
							IVDDM (percent)							
Irrigated, 2-cut	60.3	68.1	61.3	63.2	71.0	63.1	67.0	64.5	58.7	56.8	60.0	55.3	56.8	56.0
Irrigated, 3-cut	60.4	70.3	63.0	64.6	71.5	63.9	67.7	77.9	64.9	65.8	69.5	64.0	66.1	65.0
Nonirrigated, 2-cut	63.9	68.3	59.7	64.0	69.7	63.8	66.7	70.3	58.5	48.5	59.1	55.3	51.6	53.4
Nonirrigated, 3-cut	63.4	69.5	60.9	64.6	70.0	65.6	67.8	76.9	65.9	68.0	70.3	66.0	66.1	66.0
							CP (percent)							
Irrigated, 2-cut	12.0	17.5	13.6	14.4	19.4	13.2	16.3	18.6	16.8	13.3	16.2	16.7	13.6	15.1
Irrigated, 3-cut	11.8	18.7	13.3	14.6	19.9	13.7	16.8	25.1	18.9	14.3	19.4	20.1	15.0	17.5
Nonirrigated, 2-cut	15.5	16.1	12.5	14.7	17.2	12.6	14.9	20.8	19.2	14.6	18.2	18.8	14.6	16.7
Nonirrigated, 3-cut	15.2	16.3	12.2	14.6	17.3	13.0	15.1	25.1	21.9	18.1	21.7	22.6	18.4	20.5
							Plant height (cm)							
Irrigated, 2-cut	--	38	55	47	32	45	39	--	35	49	42	34	49	41
Irrigated, 3-cut	--	35	47	41	33	39	36	--	54[3/]	76[3/]	65	48[3/]	72[3/]	60
Nonirrigated, 2-cut	--	32	68	50	29	61	45	--	32	49	40	34	44	39
Nonirrigated, 3-cut	--	28	61	44	32	49	40	--	57[3/]	76[3/]	67	52[3/]	69[3/]	61
							Tawny blotch rating[4/]							
	Summer harvest													
	1975	1977	$\bar{x}$					1975	1977	1978	$\bar{x}$	1977	1978	$\bar{x}$
Irrigated, 2-cut	3.6	5.3	4.4					6.3	6.4	6.9	6.5	6.3	6.6	6.4
Irrigated, 3-cut	3.9	5.1	4.5					4.1	4.0	4.6	4.2	5.1	4.9	5.0
Nonirrigated, 2-cut	2.0	3.8	2.9					3.1	6.2	7.2	5.5	6.1	6.5	6.3
Nonirrigated, 3-cut	1.7	3.6	2.6					1.7	4.6	3.8	3.4	5.0	3.9	4.4

1/ Values are the mean of four replicates of 12 or 13 space-planted clones. Second harvest data are omitted because 2-cut plants were not harvested at that time.

2/ See table 3 for statistical significance of differences among treatment means.

3/ These values are the sum of the heights of the 2nd and 3rd harvests.

4/ Disease severity rated 1-9. 1 = no disease, 3 = slight, 5 = moderate, 7 = severe, 9 = very severe, most leaves killed.

Table 3. F values from the analysis of variance for differences between irrigation and cutting treatments within harvests and years. Based on the data of table 2

	Spring harvest					Fall harvest				
	12 clones			13 clones		12 clones			13 clones	
Source of variation	1975	1977	1978	1977	1978	1975	1977	1978	1977	1978
IVDDM										
Irrigation	38.77**	.24	8.00*	6.29*	5.50	3.67	.12	8.90*	1.48	2.47
Cutting management[1/]	.26	23.30**	18.17**	1.29	10.87*	238.27**	7.81*	192.50**	24.77**	87.06**
CP										
Irrigation	51.22**	16.01**	14.76**	13.27*	8.97*	5.92	13.01*	224.02**	19.84**	21.35**
Cutting management[1/]	.50	5.82	4.52	.17	4.63	243.90**	10.44*	80.13**	11.62*	31.63**
Plant height										
Irrigation		10.79*	62.47**	4.41	42.85**		.01	.01	3.12	2.51
Cutting management[1/]		5.66	6.67*	.98	26.58**		66.33**	2680.17**	91.68**	118.46**
Tawny blotch rating										
		Summer harvest								
Irrigation		14.41**				104.57**	.52	.46	.35	2.63
Cutting management[1/]		.84				49.74**	12.42*	95.19**	15.52**	54.73**

1/ Two cuttings (spring and fall) vs. 3 cuttings/year.

* significant at the 0.05 probability level.

** significant at the 0.01 probability level.

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